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Gas mixture enhance coalbed methane recovery technology: pilot tests

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Abstract

Gas mixture, consisting mainly of N_2 and a small amount of CO_2, enhanced coalbed methane recovery (G-ECBM) technology is a way to enhance low permeability coals' methane recovery, by taking advantage of the permeability-enhancing role of N_2. Two different scale pilot filed tests of G-ECBM have been carried out in Pingdingshan Coal Mine and in Lu'an Coal Mine. The two pilot tests were all conducted in underground tunnel. Tests results showed that, compared with existing conventional extraction method, G-ECBM technology had great breakthrough in principle and effect, and was technically feasible; gas injection had effects on not only the neighbouring production wells but also the a-little-far production wells; gas injection enhanced the concentration and flow rate of coalbed methane.

Keywords: Gas mixture, ECBM, Pilot test, Economic, China

1. Introduction

Methane (CH_4) is the second abundant greenhouse gases, just ranking behind CO_2. However, the greenhouse effect of CH_4 is about 21 times more than CO_2. There are a number of CH_4 emission sources, in which coal mining is the significant one. Coal mine gas emitted from coal mines consisted mainly of CH_4. Chinese coal mines emit about 20 Bm^3 CH_4 into the atmosphere every year. The low recovery ratio of coalbed methane has also brought about frequent gas bursts and low mining efficiency. On the other hand, CH_4 is also high-quality energy. Therefore, enhancement of the coalbed methane recovery has environmental, mining safety and economic benefits.

The Chinese government has made great efforts to enhance the recovery ratio of coalbed methane, and has developed the 11th 5-year plan of coalbed methane (coal mine gas) development and utilization, one target in which is to increase the annual output of coalbed methane to 10 Bm^3 in 2010. However, the target seems difficult to achieve. In 2009, the total output of coalbed methane is 6.17 Bm^3, and only 1.77 Bm^3 has been utilized. The fundamental reason for low recovery ratio of coalbed methane is the low permeability of most Chinese coals, and the current conventional extraction methods are not very suitable for low-permeability coal seams.

Injection of CO_2 into deep unminable coalbed is currently under development for enhanced recovery of coalbed methane (ECBM) as well as permanent storage of CO_2 [1]. In the current concept of CO_2-ECBM technology, pure CO_2 is injected into unminable coalbed to store CO_2 as more and longer as possible and to enhance the recovery of coalbed methane at the same time. Up to now, there have been 5 field test projects of CO_2-ECBM technology completed or ongoing in the world [2-5]. The common feature of the 5 field tests is that the permeabilities of coals are all higher than 1 md. However, according to the latest research by R. Gonzalez [6], the economics of CO_2-ECBM exists in many of the

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moderate permeability (10 md) coals, while fewer of the high permeability (100 md) coals and none of the low permeability (1 md) coals. This is likely a result of a balance between injectivity and primary production. In the high permeability coals, much of the methane is produced during primary recovery, resulting in a smaller ECBM prize and lesser economics. On the other hand, extremely low permeability (1 md) results in low injectivity and delayed ECBM production which hurts economics. So, how to enhance low permeability coals' methane recovery, especially 72% [7] of Chinese coals, whose permeabilities are lower than 1 md?

To overcome the problem of low-permeability, the authors attempted a method which was called as gas mixture enhanced coalbed methane recovery (G-ECBM) technology, where the gas mixture, consisting mainly of N_2 and a small amount of CO_2, is injected into the coalbed (both mineable and unmineable) through the injection wells to displace the methane from the coal and drive it toward the production wells. The key points of G-ECBM technology include: (1) taking advantage of the permeability-enhancing role of N_2 and the preferential adsorption behavior of CO_2; (2) lowering, or even eliminating the cost of gas purification. Different with CO_2-ECBM, the target of G-ECBM is to enhance the recovery ratio and production rate of coalbed methane, and to decrease the risk of gas outburst while mining, not to store CO_2.

Two different scale pilot filed tests of G-ECBM have been carried out in Pingdingshan Coal Mine and Lu'an Coal Mine. The aim of this paper is to present the detailed results of the G-ECBM pilot tests.

2. Pilot tests and results

2.1 Pingdingshan Coal Mine test

In order to verify the feasibility of the G-ECBM technology, a pilot test has been carried out in Pingdingshan Coal Mine in 2006-2007.

The Pingdingshan Coal Mine pilot test was conducted in a 620 m-deep tunnel. Fig.1 shows the design of the test. Three horizontal wells with 50m in length and 5m in spacing were drilled from the tunnel wall; the central one was used as injection well and the other two as production wells.

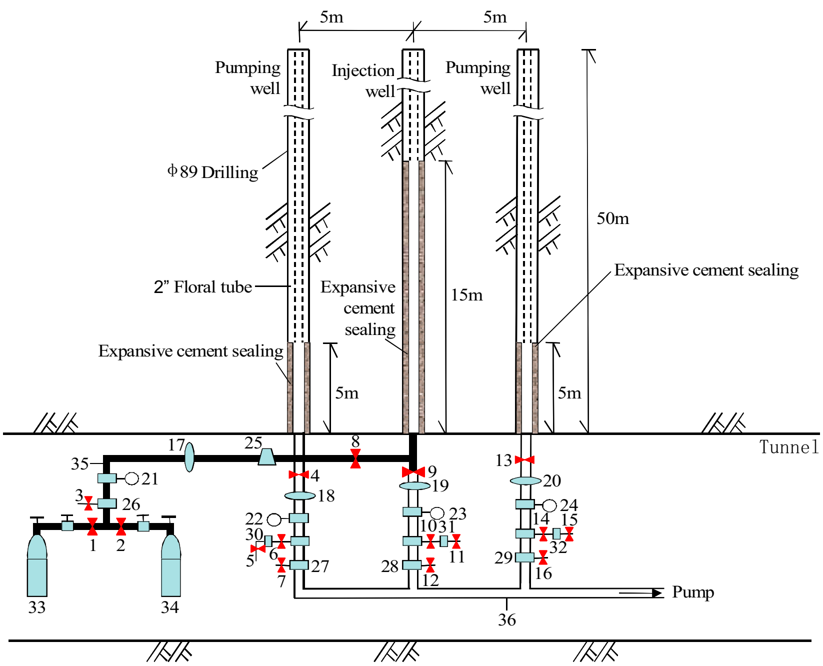

Fig.1 Design of the pilot test

In Fig.1, 1 to 16 are valves; 17 to 20 are flowmeters; 21 to 24 are manometers; 25 is safety valve; 26 to 29 are sample connections; 30 to 32 are water-gas separator; 33 and 34 are air bombs; 35 is high-pressure pipe; 36 is low-pressure pipe. All the equipments and materials used in the test were made domestically.

The test includes two stages: (1) pump-out stage - all the three wells were used to pump out coalbed methane until the production rate remarkably decreased; (2) injection stage - air (consisting of 78% N_2, 21% O_2 and 0.04% CO_2) was injected continuously through the central well at the pressure of 0.3 MPa, while the methane was produced through the other two wells. During the test, the concentration and flow rate of CH_4 in all production wells were monitored. Besides, 220 primary production wells were installed in the same tunnel.

As shown in Fig.2, after about one month production, the concentration and flow rate of CH_4 in well 1 decreased significantly. As the gas was injected into well 2, the concentration and flow rate of CH_4 in the produced gas increased obviously. Similar changes occurred in well 3, as shown in Fig.3.

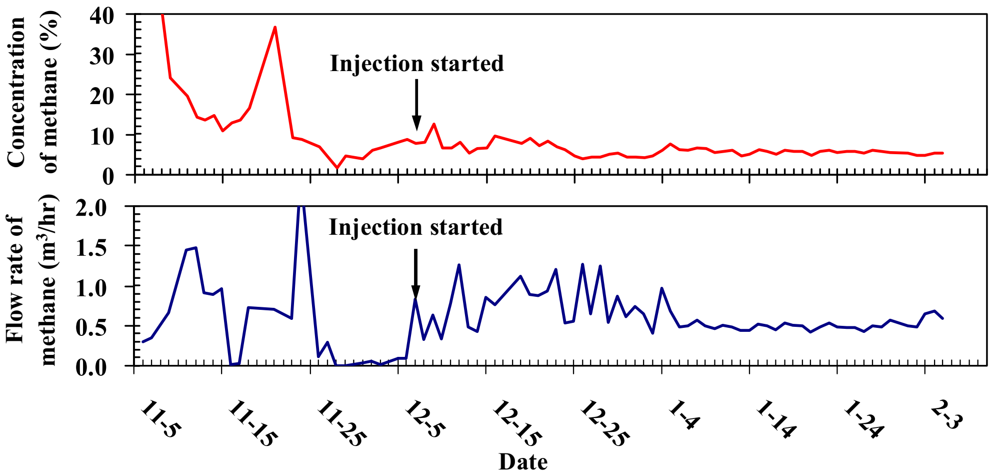

Fig.2 Changes of concentration and flow rate of CH_4 with time in well 1

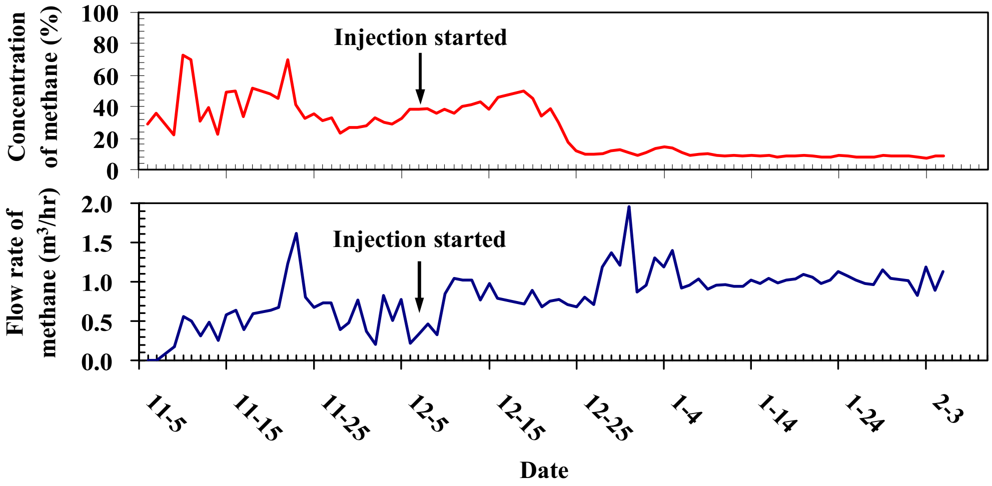

Fig.3 Changes of concentration and flow rate of CH_4 with time in well 3

Table 1 shows the average flow rate and concentration of CH_4 of test wells and other wells. Comparison of the test wells with 220 conventional production wells in the same tunnel indicated that the average single-well flow rate and concentration of CH_4 increased by a factor of 4.7 and 1.7, respectively.

The results of Pingdingshan Coal Mine pilot test have shown that G-ECBM technology can significantly improve the average single-well concentration and flow rate of CH_4. The test has also shown the technical feasibility of G-ECBM technology and the maturity of the existing domestic technology, paving a way for further conducting the large-scale tests.

Table 1 The results comparison of the test wells and the other wells

Well	Average flow rate of CH_4 (m^3/hr)	Average concentration of CH_4 (%)
1	0.86	23.5
2	0.422	43.4
3	0.63	8.6
220 conventional wells	0.13	6

2.2 Lu'an Coal Mine test

The Lu'an Coal Mine test, which has been completed in 2008, is a larger-scale test to study the influencing area of the gas injection.

Fig.4 shows the design of the test. 19 wells with 90 to 270 m in length and 6 m in spacing were selected for the test. Air injection at the pressure of 0.6 MPa was started at the beginning of the test. In order to observe the contrast effect, gas injection stopped twice in the process of the test. The concentration and flow rate of CH_4 of all production wells were monitored.

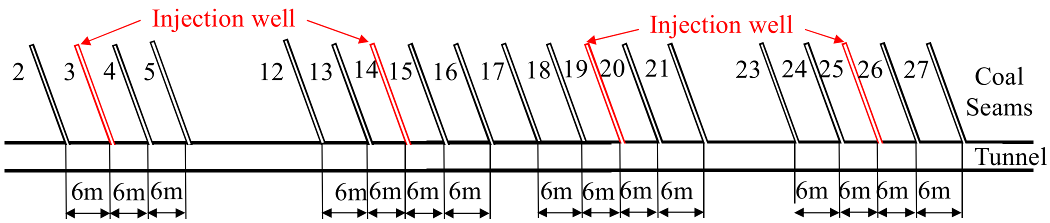

Fig.4 Layout of wells in Lu'an Coal Mine tests

We takes one test well, namely well 26, as an example to show the test results. As shown in Fig. 5, the concentration and flow rate of methane in well 26 decreased considerably during the period of injection stopped.

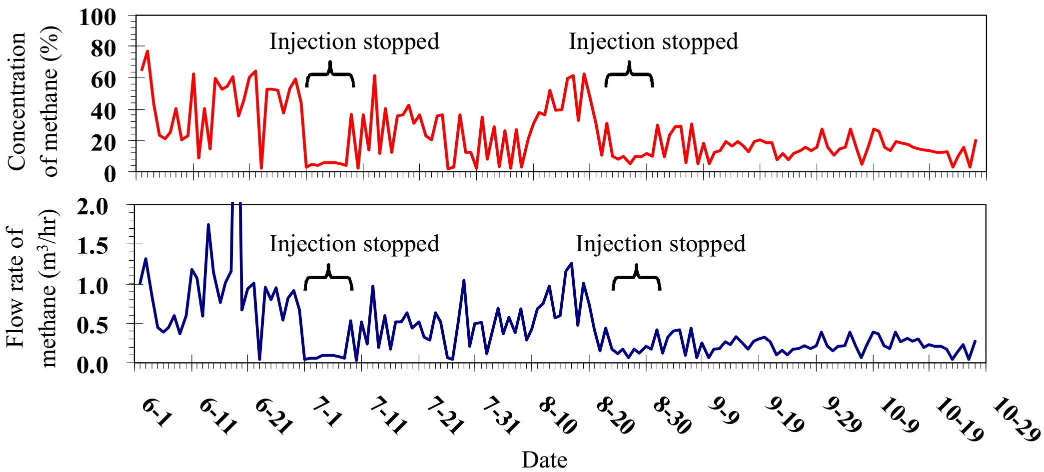

Fig.5 Changes of concentration and flow rate of methane with time in well 26

Similar changes occurred in other test wells. Comparisons of the flow rate and concentration of CH_4 in all test wells between gas injection and injection stopped were shown in Fig.6 and Fig.7, respectively. The average flow rate of CH_4 in the period of gas injection is about 1.13 to 5.06 times to that in the period of injection stopped, and the average concentration, 0.95 to 3.54 times.

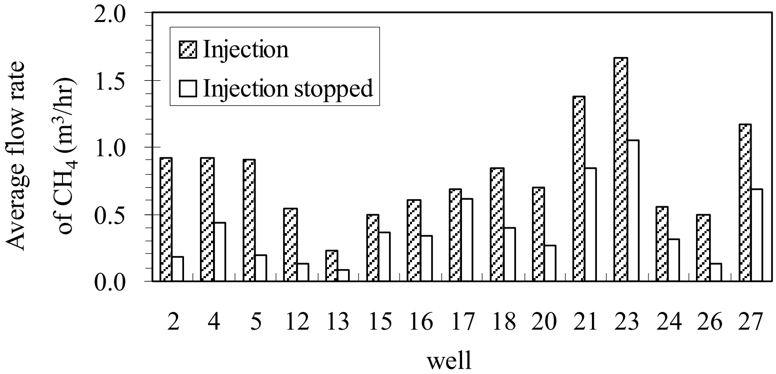

Fig.6 Comparisons of average flow rate of CH_4 in all test wells between gas injection and injection stopped

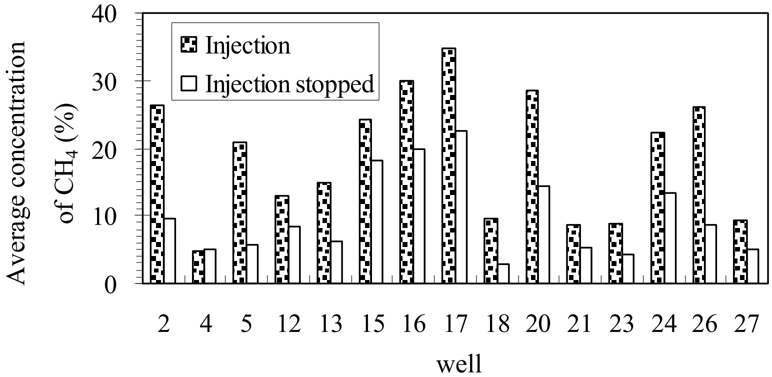

Fig.7 Comparisons of average concentration of CH_4 in all test wells between gas injection and injection stopped

3. Conclusions and future research

The results of the Pingdingshan Coal Mine pilot tests have shown the technical feasibility of G-ECBM technology. The results of Lu'an Coal Mine test shown that injection of gas enhance the concentration and flow rate of methane not only in the wells close to injection wells, but also in the further wells. However, as an emerging technology, there are many theoretical and practical problems to be solved. Future research may include: the optimal spacing between injection well and production well, injection pressure, the optimal composition of gas mixture, impact of O_2, the potential and economics of G-ECBM, and so on. Laboratory tests and numerical simulations may help to understand more about the problems.

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